Cadmium (Tank) Electroplating Alternative

(NESDI Project ID: 450)

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Technical Objectives

1.) Dem/Val Alkaline Zn-Ni (DIPSOL IZ-C17+) as an alternative to tank cadmium electroplating on high strength steel/general surfaces within Depot level maintenance

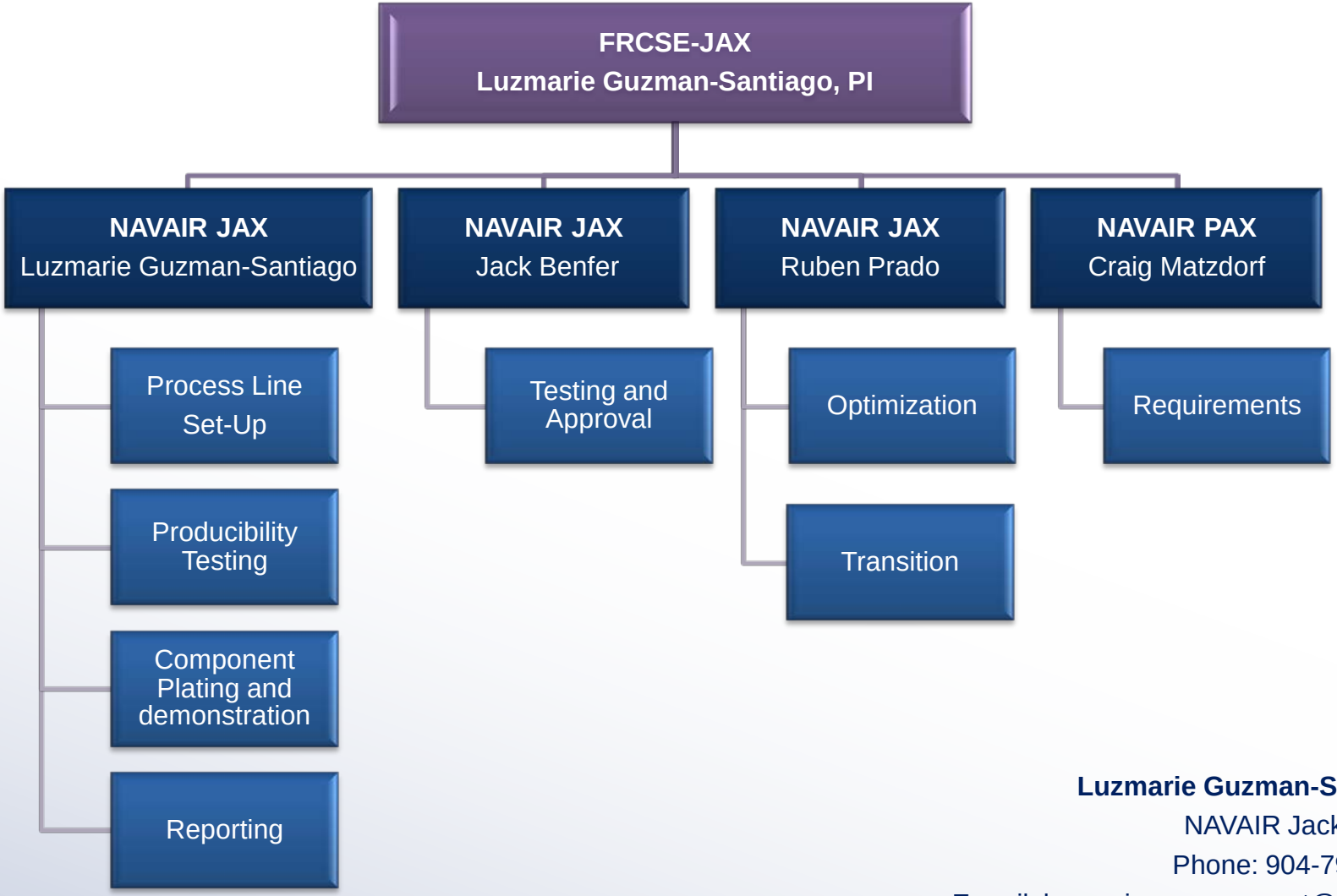
2.) Dem/Val Tri-Cr (DIPSOL IZ-264) as an alternative to conventional hexavalent post treatments on the above alkaline Zn-Ni deposit.

- Fully define deposition parameters and properties
- Establish production plating processes (i.e., cleaning, racking, masking, activation, pre-plates, stripping, etc.)
- Test/Validate performance
- NAVAIR Authorization Letter
- Develop Eng Tech Data Packages
  - Manuals
  - Specifications
  - Eng. Circular

FRCSE Toxic Metal Control Program (FRCSEINST 5103.15) requires replacement with available alternative technology.

Demo Site: FRC JAX

Project Team



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Technology Description

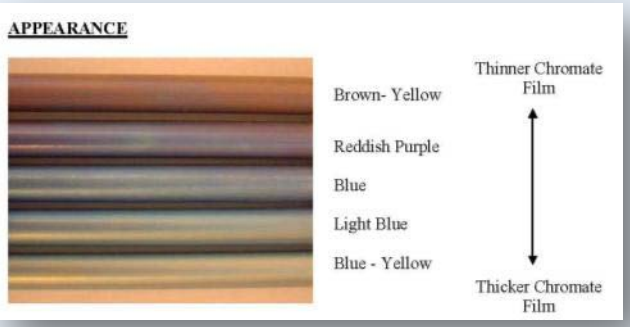
DIPSOL IZ-C17+ (Zn-Ni) & DIPSOL IZ-264 (Conversion Coating)

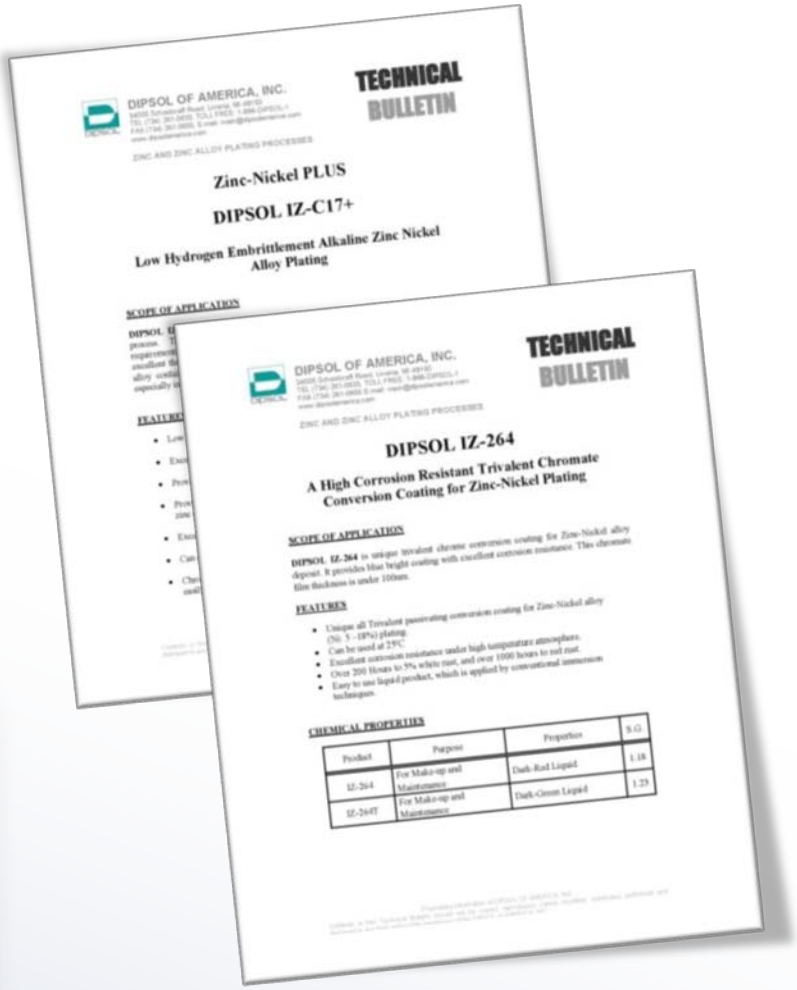
DIPSOL IZ-C17+ is an alkaline, cyanide free, Zn-Ni alloy electroplating process.

- Meets requirements for a non- embrittling process per ASTM F 519 for HSS.
- Has excellent throwing/covering power
- Uniform zinc alloy deposit containing 12 – 18% Ni
- Excellent heat and corrosion resistant properties
- Plating rate: 0.8 – 1 mil/hr @ 46.5 ASF
- Hardness: 350-450 kg/mm^2 (VHN)

DIPSOL IZ-264 is a trivalent chrome conversion coating for DIPSOL IZ-C17.

- Blue bright coating/ excellent corrosion resistance.
- Chromate film thickness is under 100nm.
- Can be applied prior to HE Baking
- Ambient Bath





Technology Description

Dem/Val Site Description

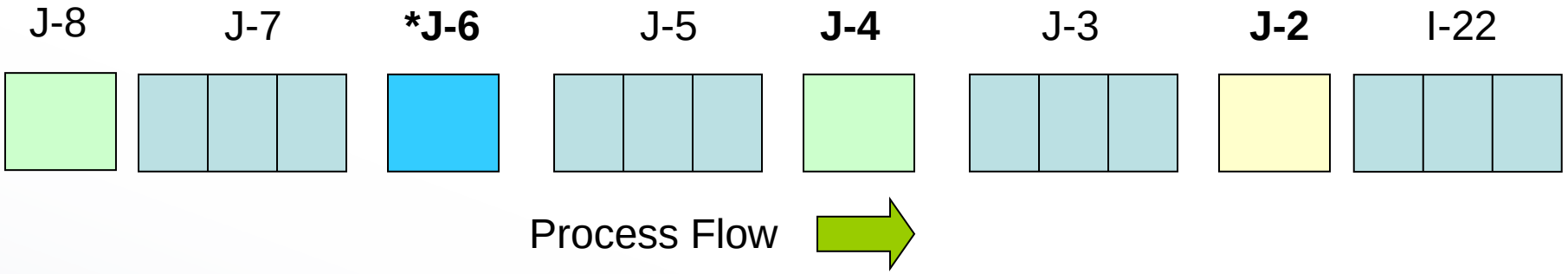
- FRCSE cyanide waste stream for FY09 was approximately 20.8K lbs (30% associated with cadmium tank electroplating).
- Existing line in FRCSE JAX Bldg 794 will be utilized for setting up the prototype line.

- **46 process tanks**
- **2 IVD Chambers**
- **23,800 ft² Plating facility**

Plating Shop Bldg 794

Technology Description

Alkaline Zn-Ni (IZ-C17+) Dem/Val Process Line, FRCSE



Tank#:	Process Step	Chemistry	Gals	Temp (°F)
J-8	Activation †	Acid	-	Ambient
J-7	Rinse	Di H20	175	Ambient
J-6	Zn-Ni Plate	Dipsol IZ-C17+	210	73 - 83
J-5	Rinse	Di H20	210	75 - 80
J-4	Activation	HCL (0.1%)	140	Ambient
J-3	Rinse	Di H20	180	Ambient
J-2	Conversion Coat	Dipsol IZ-264	135	70 - 85
J-1	Rinse	Di H20	-	140

* *Tank is to have necessary electrical requirements to support existing chiller unit, solution pump & In-tank filtration pump, heater element & associated controllers. A valve shall be put in place (chiller loop) to maintain operating temperature of bath. All plumbing, connectors, etc. are to be chemically resistant (alkaline material). † Mechanical Activation/Blasting may be used*

Demonstration Facility

- **NAVAIR Fleet Readiness Center Jacksonville**
  - Alkaline Zn-Ni Dem/Val line
  - Chiller/Solution Pump
  - 210 gallon Plating Tank
  - DC Power Rectifier

Zn-Ni Plating Tank

Integration at Hill AFB

- NAVAIR JAX Visit to Hill AFB (Phase III SBIR Effort)

Plating Line @ Hill AFB

IZ-C17+ Zn-Ni Tank @ Hill AFB

IZ-264 TriCr Tank @ Hill AFB

- Visit to ES3 facility
- Gained Lessons Learned from Hill AFB setup
- Discussed Process Flow & Plating issues

Technical Approach

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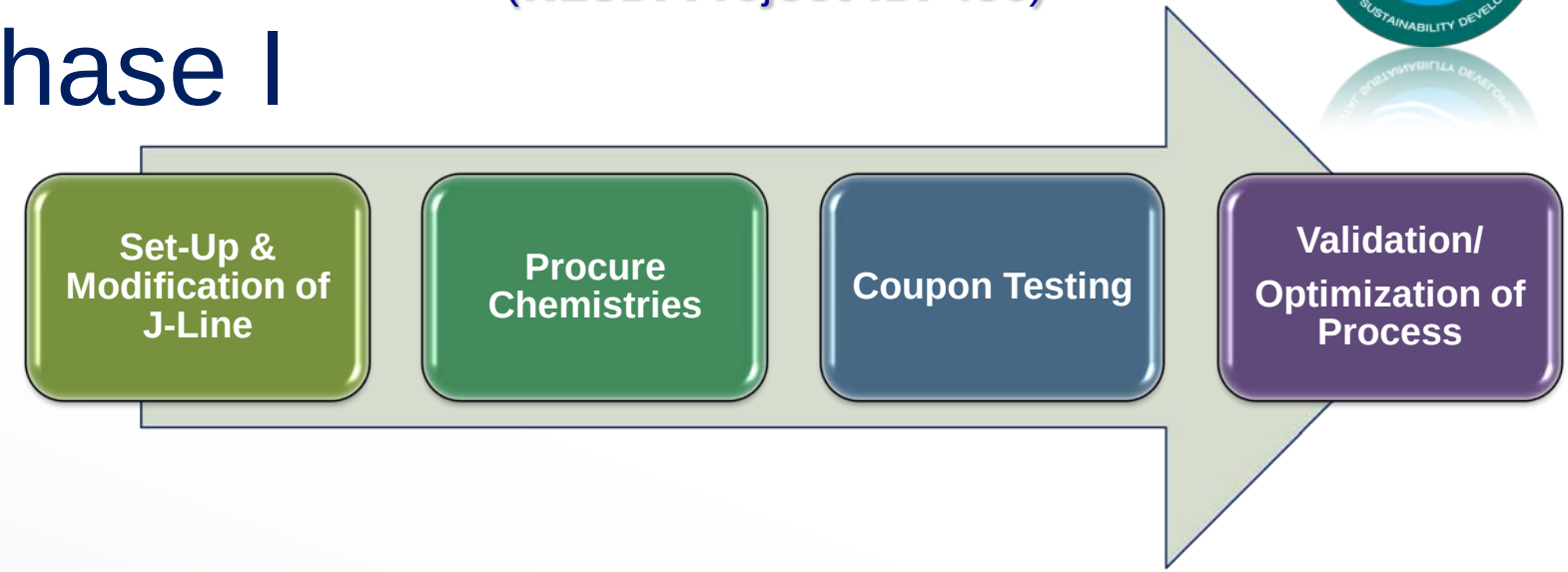
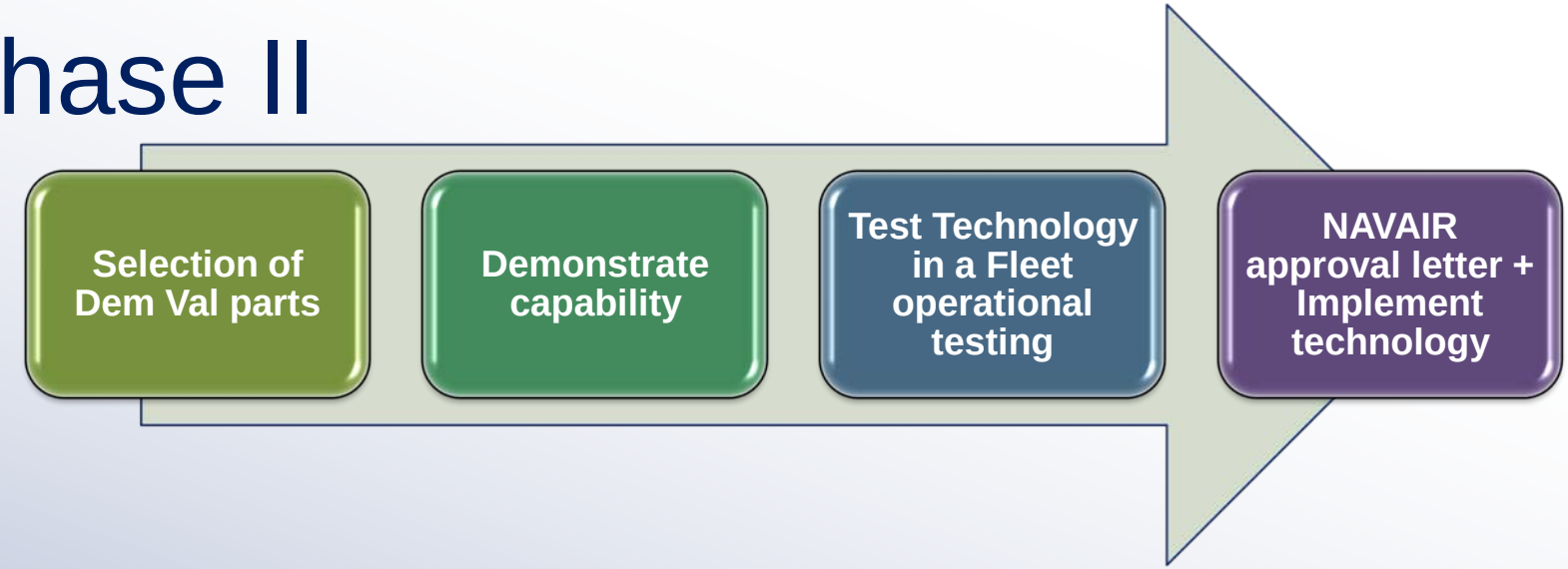
Phase I



Phase II



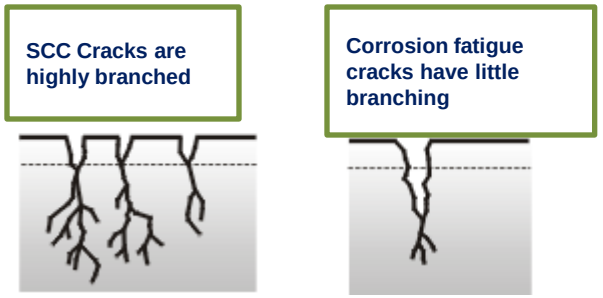
Performance Criteria (AMS 2417G)

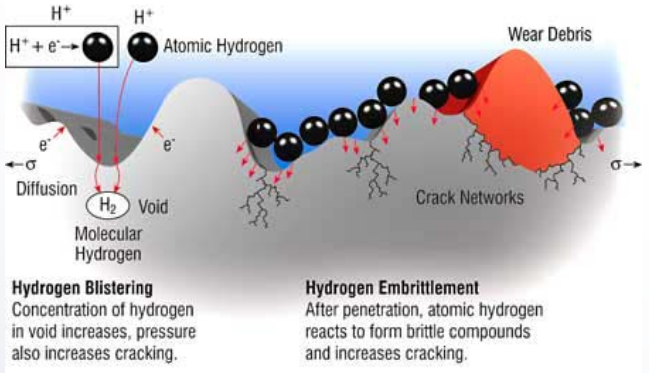
PERFORMANCE OBJECTIVES	METRIC	DATA REQUIREMENTS	SUCCESS CRITERIA
Appearance	Visual examination	Visual per MIL-STD 870B	Smooth/Continuous
Adhesion	Bend/chisel ASTM B571	180° bend to break	No lose of adhesion
Throwing Power & Alloy Composition Uniformity	(XRF) / SEM Method	Composition: 12 – 18% nickel	Consistent Alloy Composition
Thickness	Microscopic ASTM B487	Thickness measurement (mils).	Compare w/ LHE
Porosity	Ferroxyl Test	Performance => Cadmium	Compare w/ LHE
Usability	Efficiency of personnel to plate	Feedback from artisans/electroplaters on usability of technology and time requirements	Minimal operator training required
Solution Maintenance	Efficiency of personnel to analyze the solutions	Feedback from Chemist on maintenance issues	Less or equal maintenance
Corrosion (B117)	Salt fog ASTM B117	Shall not show white corrosion at the end of 96 hrs	Compare w/ LHE
Corrosion (SO_2)	SO_2 salt fog ASTM G85 A4	Dependant on thickness	Compare w/ LHE
SCC	Stress-corrosion cracking	Performance => Cadmium	Compare w/ LHE
Fatigue	Corrosion fatigue testing	Per ASTM E466	Compare w/ LHE
Hydrogen Embrittlement and Re-embrittlement	Hydrogen embrittlement ASTM F519	HE: 75% NFS 200 hrs HRE: 45% NFS 150 hrs	Threshold limit greater than /equal to LHE Cd

Performance Criteria

Key Performance Criteria

- ***Stress Corrosion Cracking:*** Evaluate effect of the Zn-Ni coating on the fracture properties of the underlying substrate as compared to Cadmium.
- ***Corrosion Fatigue – ASTM E466-96:*** Evaluate effect of the Zn-Ni coating on the fatigue performance properties of the underlying substrate as compared to Cadmium.
- ***Corrosion – ASTM B117 and G85:*** Evaluate corrosion protection using standard accelerated corrosion tests. The protocol includes both corrosion ranking (amount of corrosion product on the surface) and protection ranking (extent of coating damage), to provide an overall assessment of corrosion performance.
- ***Hydrogen Embrittlement – ASTM F519:*** Evaluate process susceptibility to hydrogen embrittlement and characterize environmentally assisted cracking per ASTM F519.



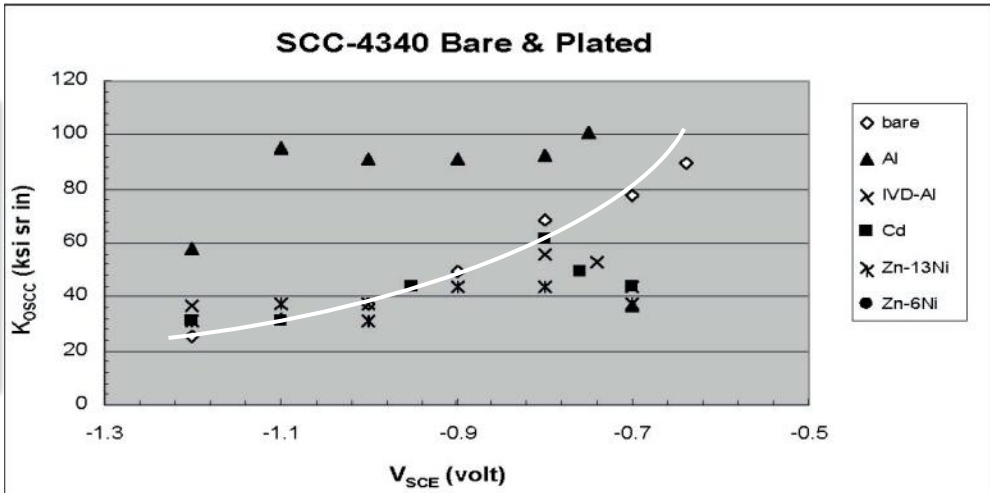


SCC Testing

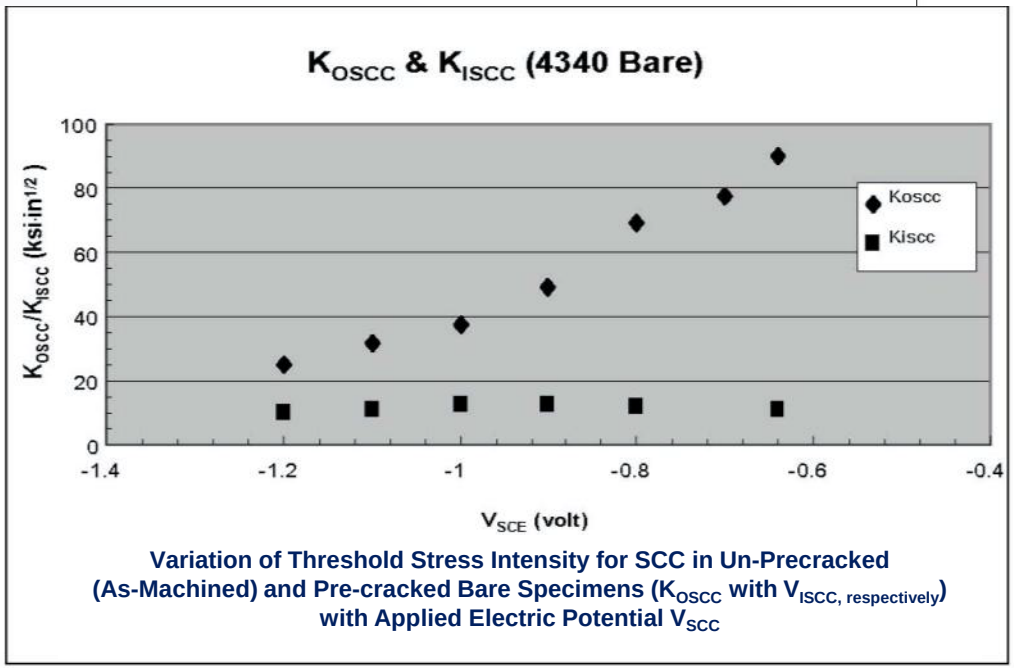
SCC Testing

Test Details:

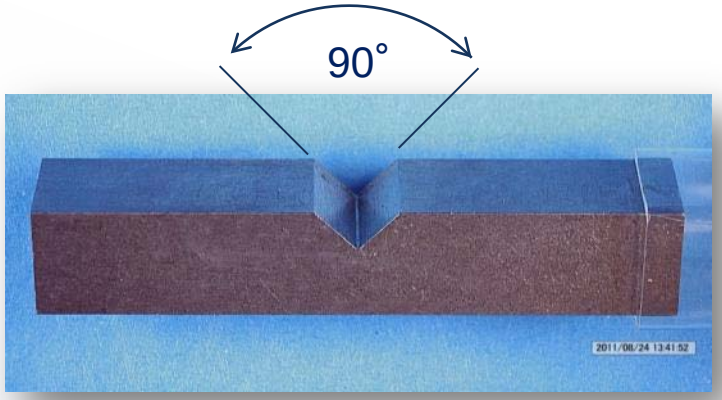
- RSL on notched four point bend specimens and determine threshold stress for initiation of SCC cracks.
- ASTM F519, Type 1.e notched square bar
- Conduct at 3.5% NaCl at OCP w/ Cathodic Over-Potential
- Report: V_{SCE} –vs- K_{OSCC}
- Report: K_{OSCC} at OCP (ksi-√in)



Variation of K_{OSCC} with V_{SCC} for Bare and Coated Specimens



Variation of Threshold Stress Intensity for SCC in Un-Precracked (As-Machined) and Pre-cracked Bare Specimens (K_{OSCC} with $V_{ISCC, respectively}$) with Applied Electric Potential V_{SCC}

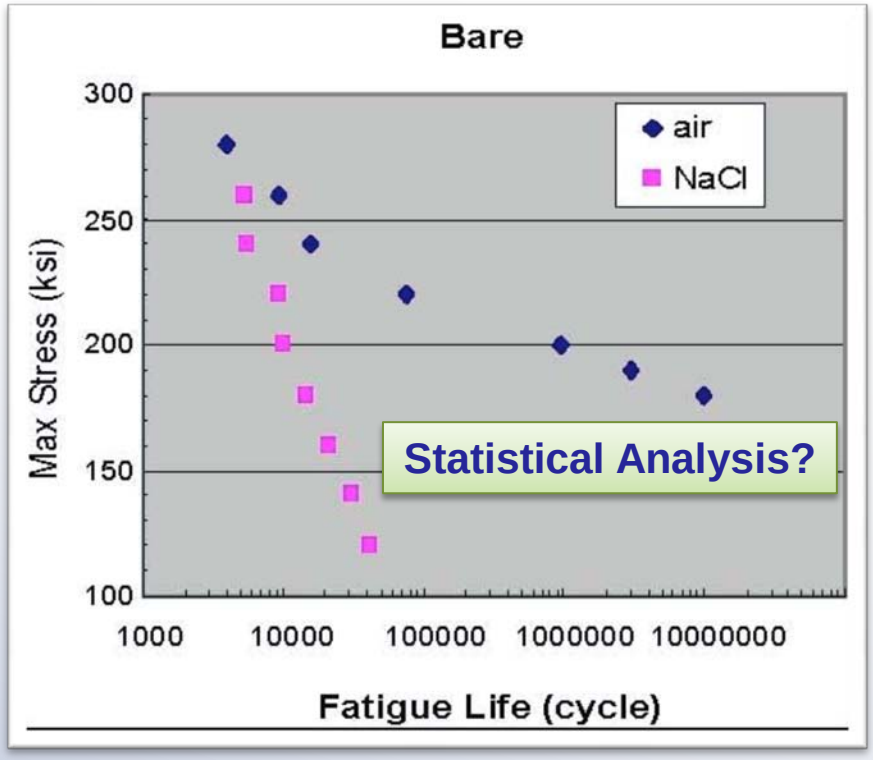


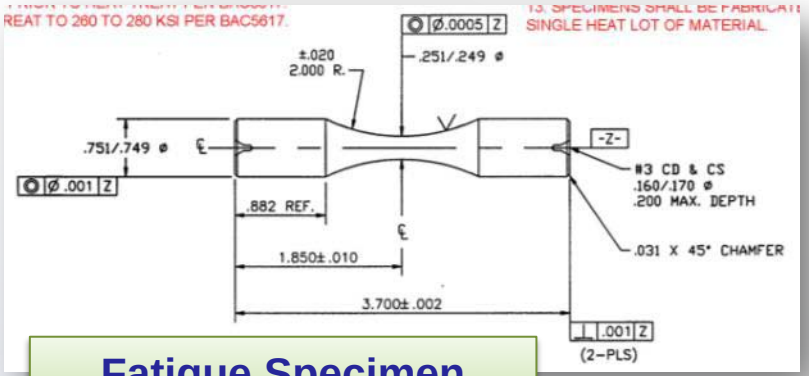
Type 1.e Notched Square Bar
52-54 HRC

Fatigue Testing

Corrosion Fatigue

- ASTM E466
- AISI 4340, 260-280 KSI
- R= 0.1, f=10hz
- Air, 3.5% NaCl (pH 7.3)
- Generate S-N Curve
- Hour Glass Bar (20/Condition)

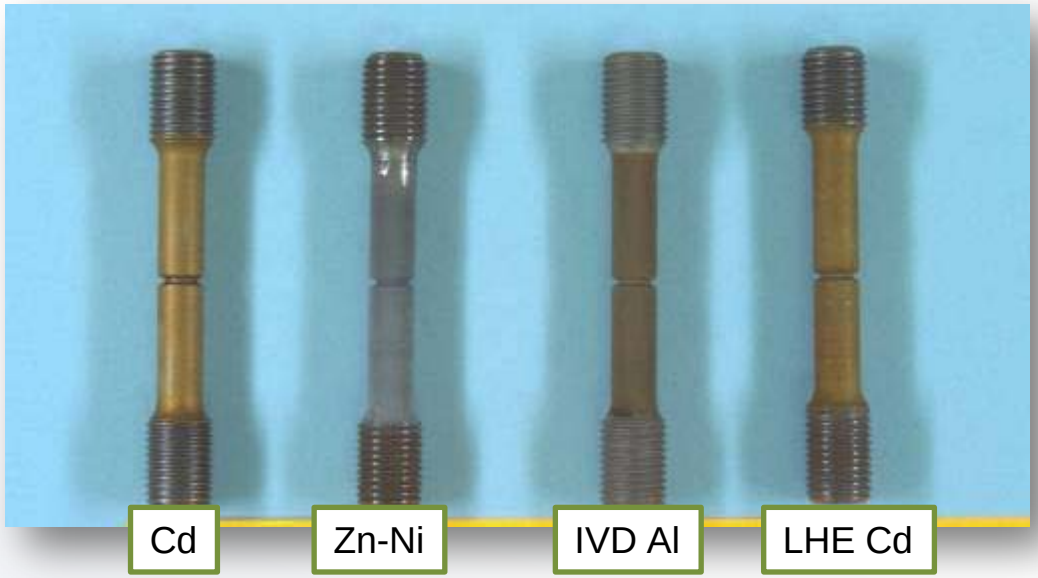




Fatigue Specimen

HRE Testing

Environmentally Assisted Cracking



Specimens:
ASTM F519 1a.1 Notch Bars
AISI 4340 Alloy Steel, HRC 50-52
NFS is 390 KSI

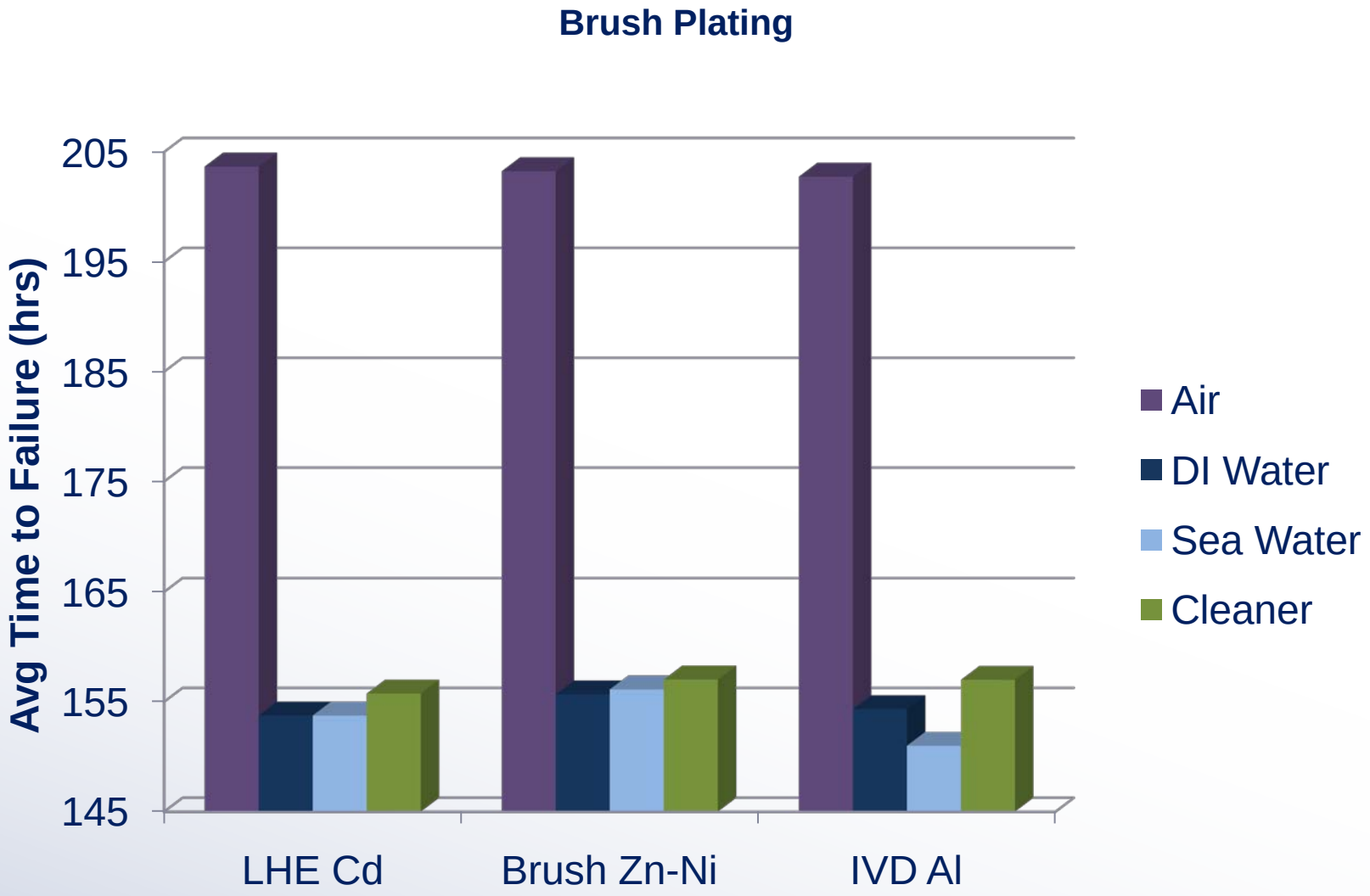
Re-Embrittlement Test Fluids:
- DI Water, ASTM 1132, Type 2
- Synthetic Sea Water, ASTM D 1141 (2.5 or 3.5% NaCl)
- MIL-PRF-85570, Type II Cleaner

Recommendations

Test Details:
- ASTM F519
- 45% NFS for 24 hrs +5ksi/hr (Phase I)
  or 45% NFS 150 hrs +5ksi/hr (Phase II)
- Recommend 90° Notch Test Specimens
- Reporting Sustained/Threshold load (%NFS), Time to failure.

Hydrogen Re-Embrittlement Test Equipment

Hydrogen Embrittlement/HRE
ASTM F519 A5, Type 1.a.1



Questions

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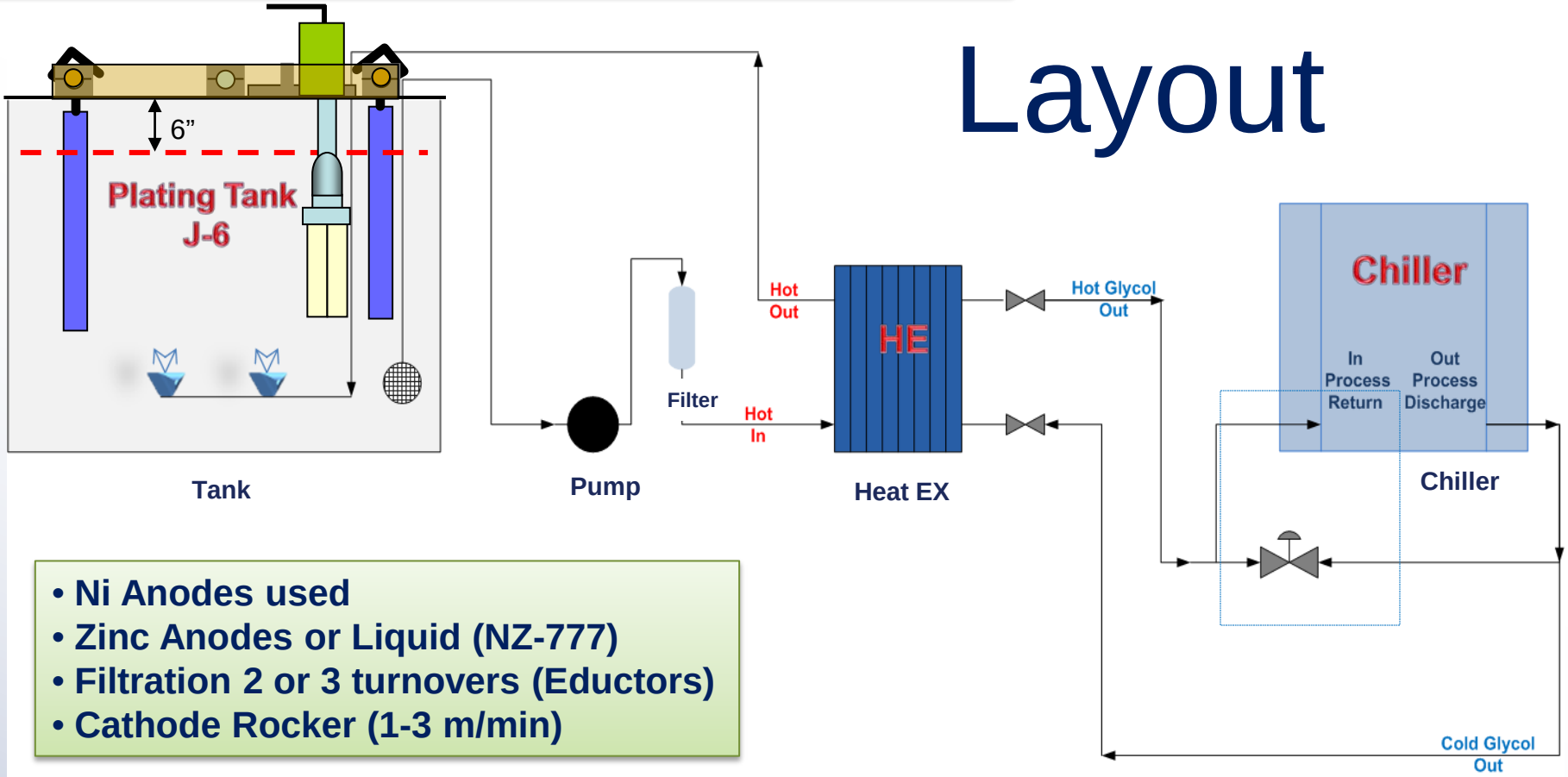
Backup Slides

Technology Description

Equipment Set-Up for IOC at JAX



- Ni Anodes used
- Zinc Anodes or Liquid (NZ-777)
- Filtration 2 or 3 turnovers (Eductors)
- Cathode Rocker (1-3 m/min)

Cd Brush Plating Alternative
LHE Zinc-Nickel

FRCSE Evaluation of Brush Zn-Ni

Corrosion (B-117/SO2)

- Overall B-117 showed Cd repair area to perform better than Zn-Ni
- Overall Painted SO2 performance rating (1 = Best; 4 = Worst):

1 – LHE Cd/Cd
2 – ZnNi/Cd
3 – LHE Cd/IVD
4 – ZnNi/IVD

Hydrogen Embrittlement/Re-Embrittlement

- All coupons passed (LHE Cd, IVD Al, & Brush Zn-Ni)
- Zn-Ni showed slight performance increase compared to baseline (however, with more variability)

Production Application

- Process sensitivity – Current Density
- Appearance
- Odor

Hydrogen Embrittlement/HRE
ASTM F519 A5, Type 1.a.1

Brush Plating

Air

Envirnment	Coating	Replicate	FRACTURE STRENGTH (%)	TIME TO FAILURE (HRS)	Pass/Fail
Air	LHE Cd	1	94.0%	204	Pass
		2	Failed after 9 Hrs		
		3	90.0%	203	
		4	93.3%	204	
	IVD Al	1	84.6%	201	Pass
		2	88.7%	203	
		3	93.8%	204	
		4	90.4%	203	
	Brush Zn-Ni	1	97.0%	200	Pass
		2	94.8%	204	
		3	95.2%	204	
		4	97.6%	205	

200 hr Sustained Load Test at 75% NFS then step 5% per hr until failure

DI Water

Environment	Coating	Replicate	FRACTURE STRENGTH (%)	TIME TO FAILURE (HRS)	Pass/Fail
Di Water	LHE Cd	1	65.2%	154	Pass
		2	60.0%	153	
		3	65.3%	154	
		4	65.6%	154	
	IVD Al	1	Failed after 131 Hrs		Pass
		2	70.2%	155	
		3	55.0%	152	
		4	75.4%	156	
	Brush Zn-Ni	1	Failed after 101 Hrs		Pass
		2	80.1%	157	
		3	75.5%	156	
		4	65.1%	154	

Sea Water

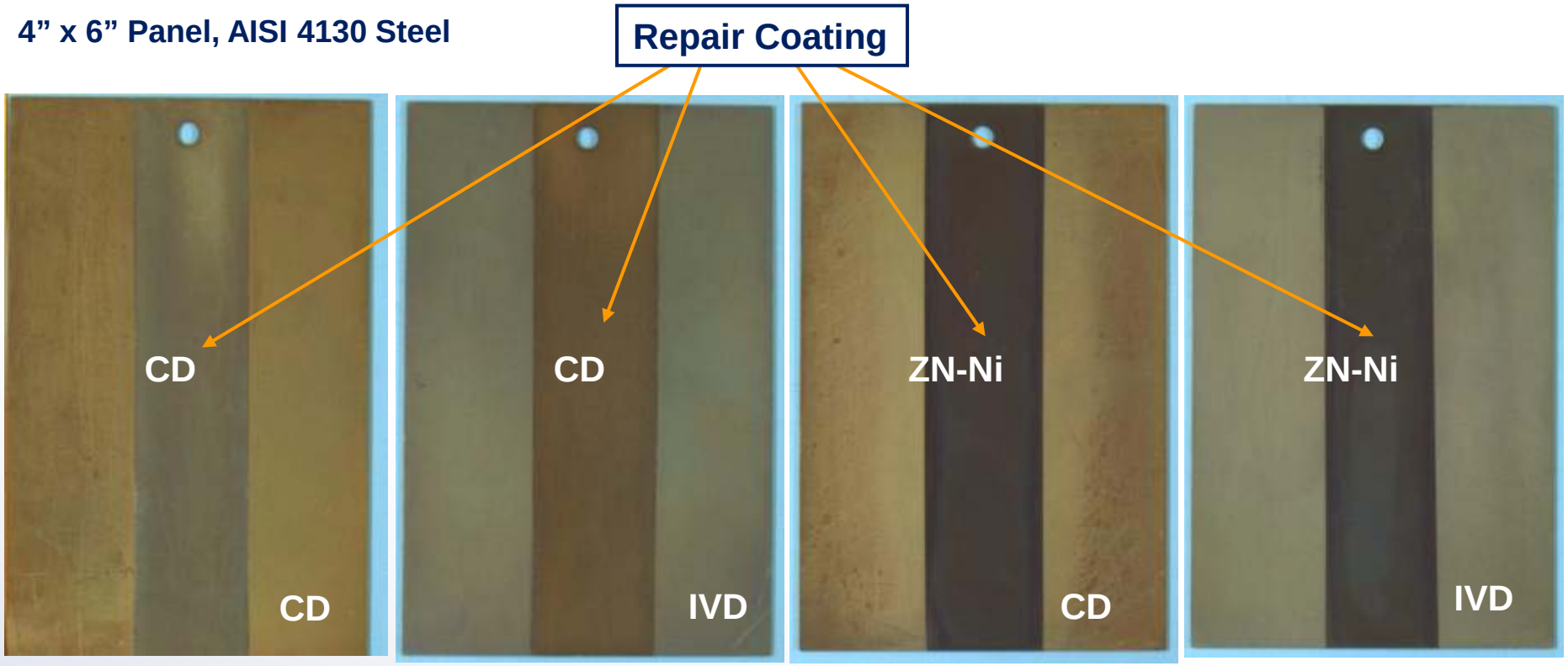
Environment	Coating	Replicate	FRACTURE STRENGTH (%)	TIME TO FAILURE (HRS)	Pass/Fail
Sea Water	LHE Cd	1	65.2%	154	Pass
		2	60.0%	153	
		3	65.3%	154	
		4	65.6%	154	
	IVD Al	1	Failed after 5 min		Pass
		2	55.1%	151	
		3	55.1%	151	
		4	50.5%	151	
	Brush Zn-Ni	1	55.0%	152	Pass
		2	115.3%	165	
		3	Failed after 10 min		
		4	55.0%	151.4	

MIL-PRF-85570, Type II Cleaner

Environment	Coating	Replicate	FRACTURE STRENGTH (%)	TIME TO FAILURE (HRS)	Pass/Fail
MIL-PRF-85570 Type II Cleaner	LHE Cd	1	60.3%	153	Pass
		2	60.2%	153	
		3	85.6%	158	
		4	90.1%	159	
	IVD Al	1	89.2%	159	Pass
		2	90.4%	159	
		3	50.2%	151	
		4	90.4%	159	
	Brush Zn-Ni	1	75.5%	155.1	Pass
		2	90.1%	159	
		3	80.4%	157	
		4	80.4%	157	

Repair Test Panels

4” x 6” Panel, AISI 4130 Steel



LHE Cd (2023) on Cd Plating (Tank)

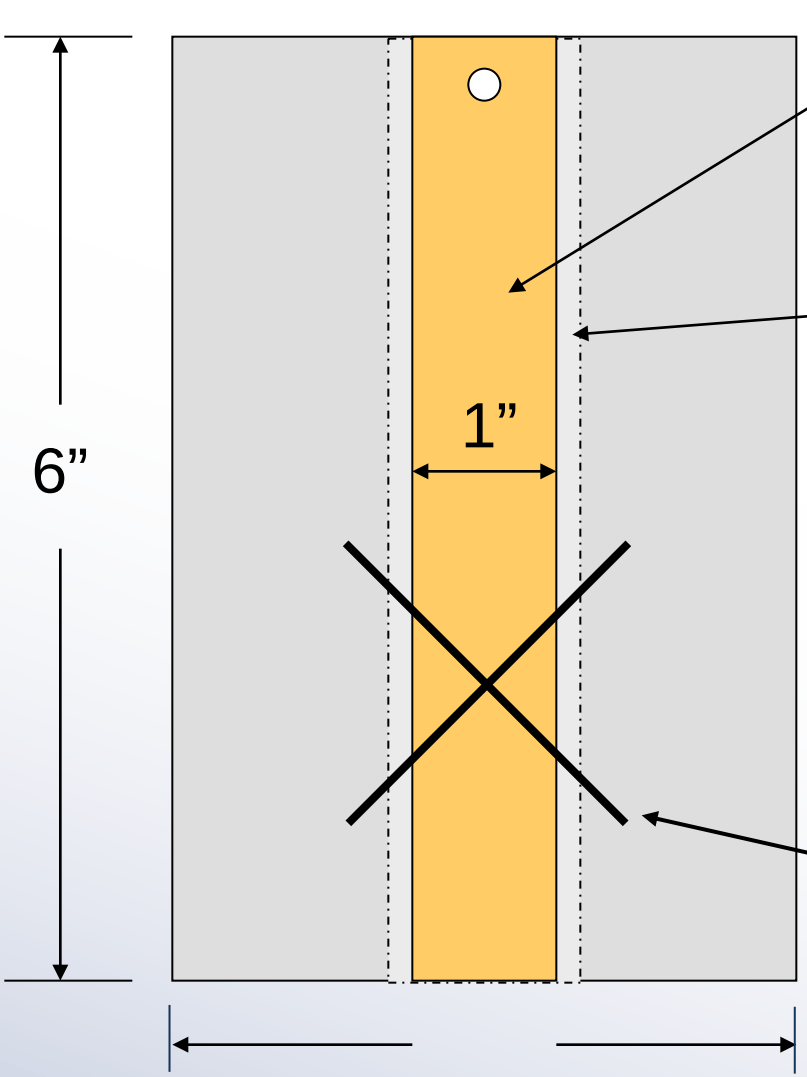
LHE Cd (2023) on IVD Aluminum

SIFCO 4018/5970 Zinc-Nickel on Cd Plating (Tank)

SIFCO 4018/5970 Zinc-Nickel on IVD Aluminum

Brush Plate Repair Configuration

Brush Plating



Area to be Brush Plate Repaired

Up to ~ 0.5” overlap is allowed

NOTES:
4” x 6” Steel Panel
Substrate material: AISI 4130 Steel
Plating per Manufacturer Instructions
Target thickness: 0.5 mil

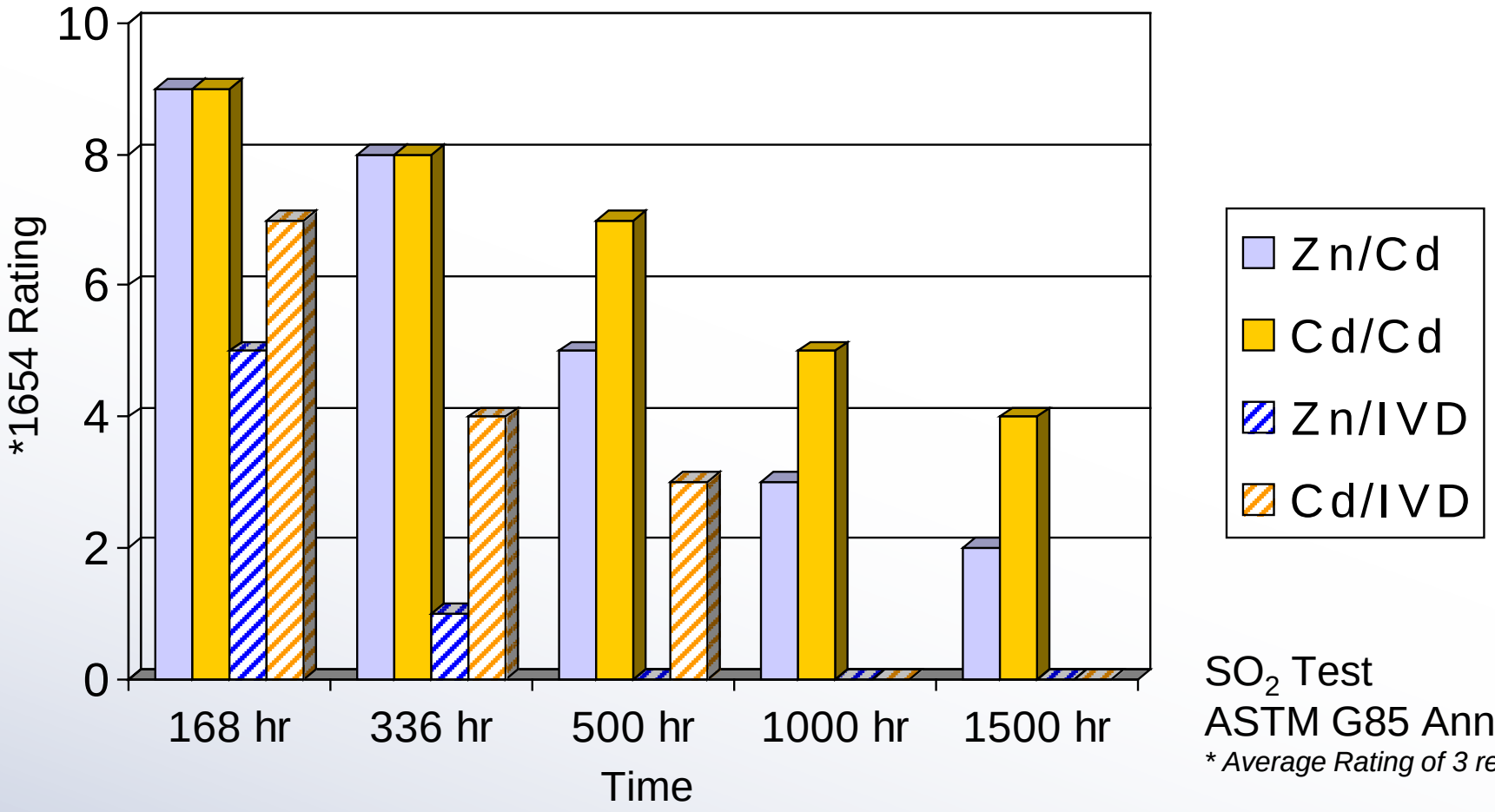
Primer = MIL-PRF-85582
Top Coat = MIL-PRF-85285

Brush Plated Repair

Existing Plated Area, Cd or IVD

Scribed Area

Brush Plate Repair Configuration



SO_2 Test
ASTM G85 Annex 4
** Average Rating of 3 replicates*

Throwing Power

Throwing Power/Composition Uniformity

Capped end polypropylene Tube

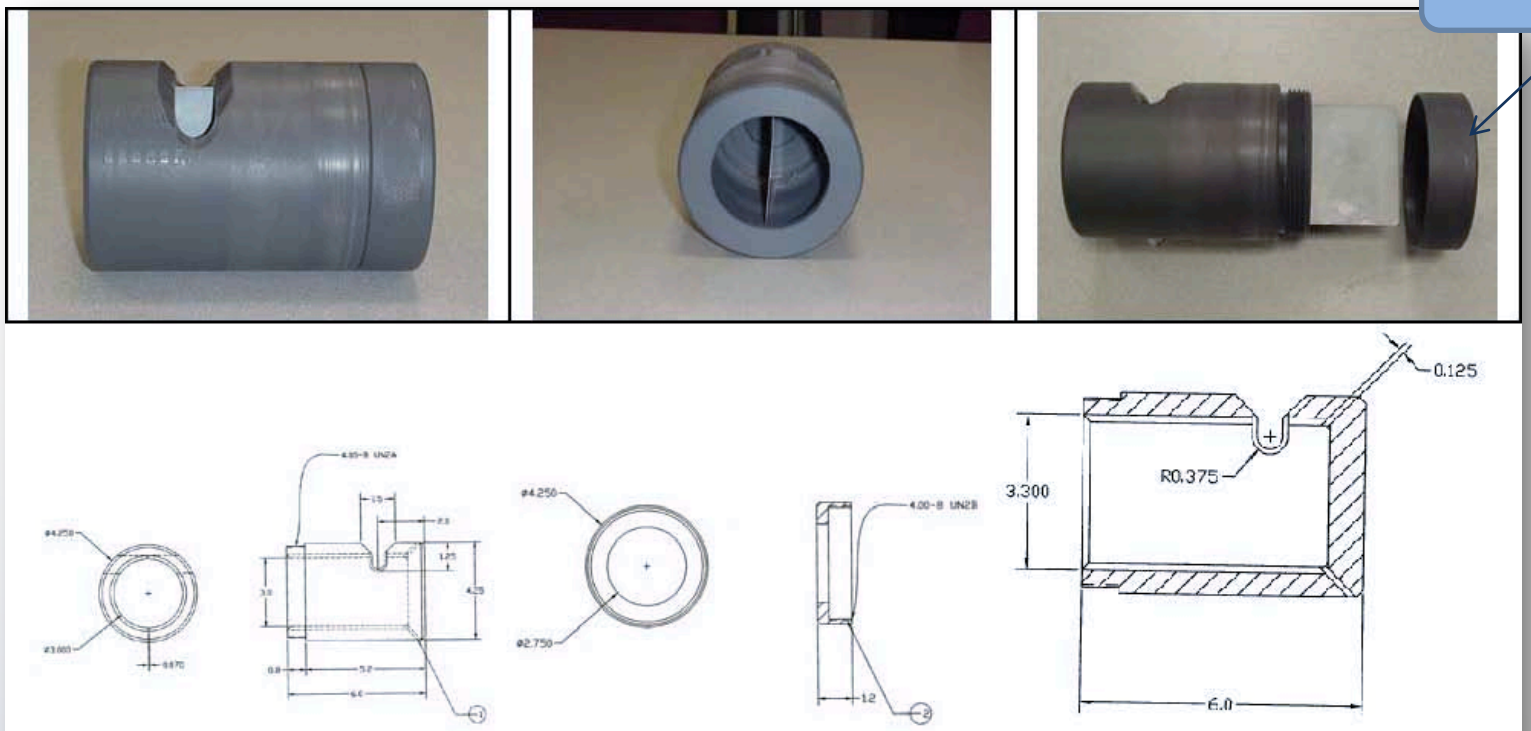


Figure 12. Fixture for "Throwing Power" and Alloy Composition Test

Test Methodology:

- AISI 4340 Steel Coupons (different orientations to "coating" chamber)
- Measure coating thickness (several locations along panel, ASTM B568)
- Measure Alloy Composition across surface using X-Ray Fluorescence Spectrometry (ASTM E1621)
- Acceptance Criteria: Composition stays within specs. (Document thickness variation.)